Source Sizes in Nuclear Multifragmentation

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It was previously shown that the observed charge distributions resulting from nuclear multifragmentation obey the following invariant form [1]:

$$P_n(Z) \propto \exp\left(-\frac{B(Z)}{\sqrt{E_t}} - cnZ\right) \quad (1)$$

where n is the total intermediate mass fragment (IMF:$3 \leq Z \leq 20$) multiplicity of the event; E_t is the total transverse energy ($E_t = \sum_i E_i \sin^2\theta_i$, where E_i is the kinetic energy of charged particle i in an event, and θ_i is its polar angle); and $B(Z)$ is the "barrier" distribution.

From thermodynamic considerations and percolation simulations, it was shown that c in Eq. (1) vanishes when the gas of IMFs is in equilibrium with a liquid (residue source, or percolating cluster), and assumes a value $\propto 1/Z_0$ (Z_0 being the source size) when the source is wholly vaporized [1–3].

Experimentally, the parameter c undergoes an evolution with energy from approximately zero to a non-zero positive constant [2]. Thus the source size evolves from near infinity (an "infinite" reservoir of fragments) to the actual size of the source. This interpretation gives insight both into the prevailing equilibrium conditions and also into the source size.

A new empirical feature observed in many reactions has led us to a complementary method of independently determining the source size.

It has been shown that the total fragment multiplicity distribution P_n at any given E_t is *empirically* given by a binomial distribution [3]

$$P_n = \frac{m!}{n!(m-n)!}p^n(1-p)^{m-n}. \quad (2)$$

This implies that fragments are emitted nearly independently of each other, so that the probability P_n of observing n fragments can be written by combining a single one-fragment emission probability p according to Eq. (2). The parameter m (the total number of throws) represents the maximum possible number of fragments, which is immediately related to the source size. A simple way to obtain the size of the source is to multiply m by the average fragment size.

The natural next step is to restrict the fragment definition to a single atomic number Z. Thus, we have attempted binomial fits of the multiplicity distributions for *individual* Z values to extract the number of throws m_Z associated with fragment emission of a given Z [4]. The source size Z_0 is then equal to Zm_Z. Values for Z_0 (averaged over Z values from 3 to 6) are given on the ordinate in Fig. 1 from central collision data of the indicated reactions.

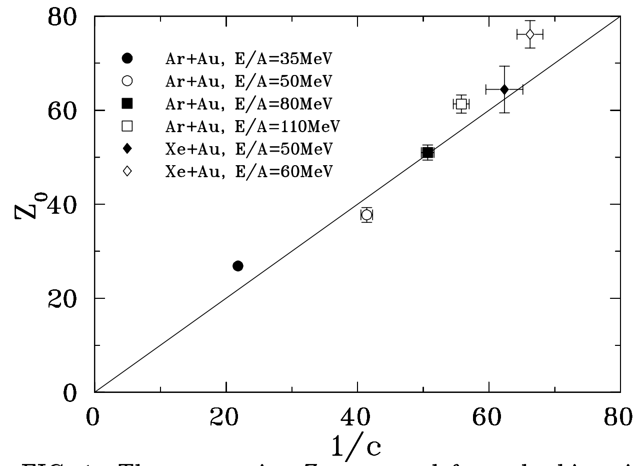

FIG. 1. The source size Z_0 extracted from the binomial analysis as a function of the source size ($1/c$) determined as per ref. [1] from central collisions of the indicated reactions.

Let us now return to the source size determined from the parameter c [1,2]. If the parameter c is interpreted as $1/Z_0$, the source size calculated from c is large (near infinity) at low E_t, reflecting the fact that the source residue acts as an "infinite" reservoir of charge. At high E_t, however, when the source residue disappears, the extracted value of Z_0 should stabilize around the actual size of the source. Thus, it is possible to plot the value of Z_0 determined from m_Z against that obtained from the c parameter (both for the top 5% most central collisions in E_t). This is shown in Fig. 1.

The result is striking. Not only are the two quantities well correlated, but they also agree in absolute value within the precision of the measurements! The strong corroboration that the two approaches offer to each other gives confidence that we have gained direct access to the source size. This source is specifically the entity that generates fragments through "chemical equilibrium". It does not contain the pre-equilibrium part often incorporated in other source reconstruction methods.

[1] L. Phair *et al.*, Phys. Rev. Lett. **75**, 213 (1995).
[2] L.G. Moretto *et al.*, Phys. Rev. Lett. **76**, 372 (1996).
[3] L.G. Moretto *et al.*, Phys. Rep. **287**, 249 (1997).
[4] L.G. Moretto *et al.*, submitted to Phys. Rev. Lett., LBNL 42646.